Modeling and Observations of Surface Waves in Monterey Bay

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LONG-TERM GOALS

The long-range goals of this project are to develop an improved turbulence closure model that takes explicit account of surface wave effects and to quantify the effect of Stokes drift on the surface current signature of High Frequency (HF) radar systems.

OBJECTIVES

The objectives of this project are to: 1) deploy a surface buoy with turbulent flux and surface wave measurement capabilities within the footprint of the HF radar network in Monterey Bay and 2) formulate a new turbulence closure scheme based on surface wave dynamics that can be evaluated using data from the flux buoy.

APPROACH

This project is extending the measurement and modeling efforts already underway in the Monterey Bay region to include the direct measurement and modeling of surface waves.

WORK COMPLETED

Assembly and deployment of the NPS Flux Buoy has taken place, a sixty-day record has been collected so far, and a buoy recovery and turn-around has been scheduled for November 1999. The initial formulation of a new turbulence closure scheme based on surface wave dynamics has been completed along with preliminary validation experiments.

RESULTS

An instrumented toroid buoy was assembled, checked out and deployed in Monterey Bay to provide in situ measurements of surface waves and atmospheric forcing by K. Davidson of the NPS Meteorology

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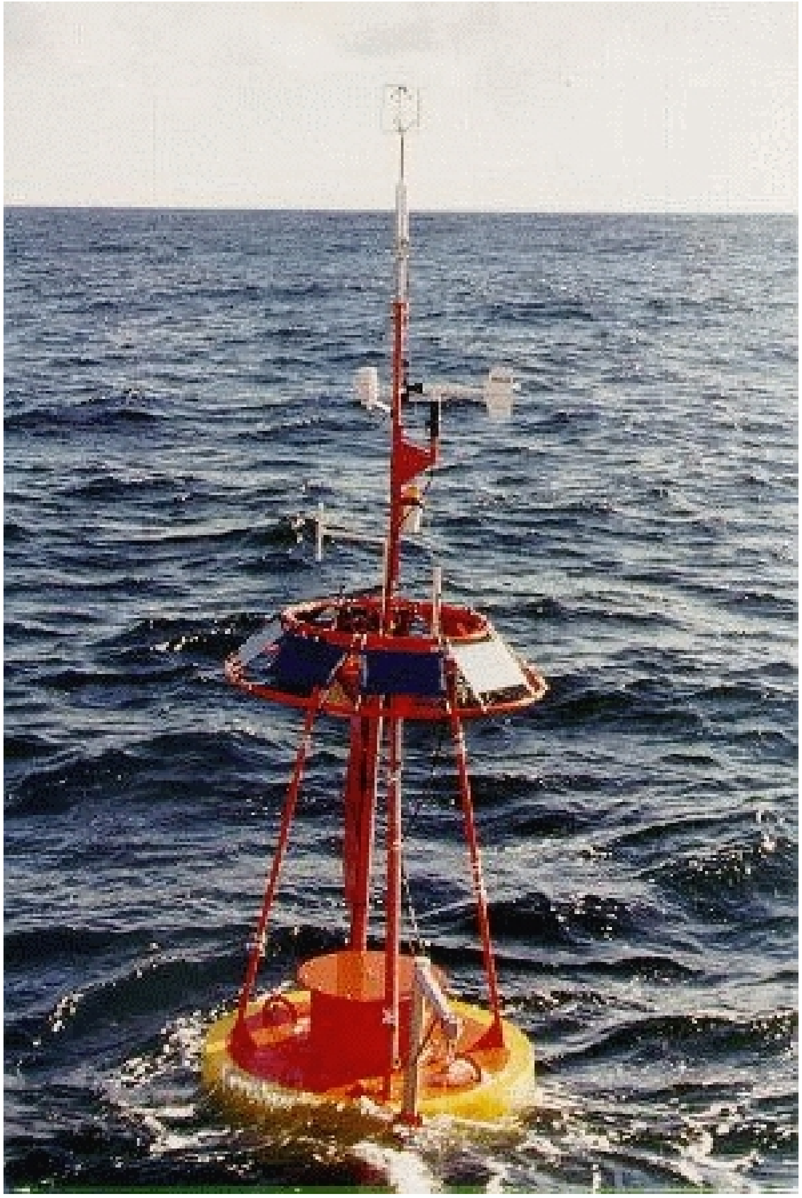
Department. The parameters measured by the NPS Flux Buoy are shown in Figure 1. The buoy was deployed on 2 September 1999, approximately, 9 km west of Moss Landing. It has operated continuously since then and recovery and redeployment are planned for the week of 8 November 1999. A significant effort in pre-launch preparation was made to install and evaluate onboard solar-cell power generation in order to extend the buoy operation period up to the limit of the available onboard memory. The determining factors in this case are the 20 Hz sampling rates of the sonic anemometer and buoy accelerations needed for airflow turbulence and surface wave data, respectively. Both of these data streams are primary to the objectives of the project. Mean (i.e., bulk) airflow and SST data are stored onboard the buoy using much lower sampling rates. The bulk data are also sent via radio (RF) link to shore where they are used in real-time diplays and as checks on the buoy operating conditions. Examples of this data and other mooring-related data for Monterey Bay can be seen at: http://www.oc.nps.navy.mil/~icon/moorings/ . An example of the type of data being received for real-time instrumentation and condition assessments during one twenty-four hour period is shown in Figure 2. The diurnal and shorter period variations visible in the figure are typical of the type of information that will be combined with the surface wave and turbulent fluxes after the onboard data is retrieved.

L. Ly has developed a primitive equation circulation model for the Monterey Bay region (MOB) based on an adaptation of the Princeton Ocean Model (POM) and multi-block grid techniques. The MOB response to mesoscale wind forcing by the NCAR atmospheric model (MM5) was investigated and compared with a companion simulation forced by spatially constant observed winds. Sixty-day simulations using springtime MM5 wind forcing show the basic physics of two strong upwelling centers around a warm anticyclone in June. The upwelling center locations, surface cold coastal currents, and temperature and salinity magnitudes agree well with prior observations. The companion run forced by spatially constant buoy winds did not reproduce these expected features. These results have been written up for the AMS Third Conference on Coastal Atmospheric and Oceanic Prediction and Processes to be held in New Orleans in November 1999.

A new surface wave parameterization was developed using surface turbulence energy fluxes and diffusion. Simulations show that models using the new coupled air-wave-sea scheme better reproduce dissipation distributions and other physical characteristics in the ocean than models using the previous scheme (Ly, 1995; Ly and Garwood, 1999), or the classical wall-layer theory, when compared with available measurements as shown in Figure 3. A description of this parameterization scheme is available in draft form (Ly, Garwood and Paduan, 1999) and was presented at the AMS Thirteenth International Symposium on Boundary Layers and Turbulence held in Dallas, TX, in January 1999. The new closure scheme has been implemented within MOB using the pivotal-condensation numerical method. That implementation is being debugged now. The next step will be to transfer subroutines for the new scheme to the POM-based Monterey Bay model being used with local data assimilation by I. Shulman as part of the National Ocean Partnership Program's Innovative Coastal-Ocean Observing Network (NOPP/ICON). A second turbulence closure scheme with a wave (spectral) parameterization has been developed using wave mean momentum and wave kinetic energy by Ly and Benilov. This scheme will also be incorporated into an air-wave-sea coupled model to test the output against observational data.

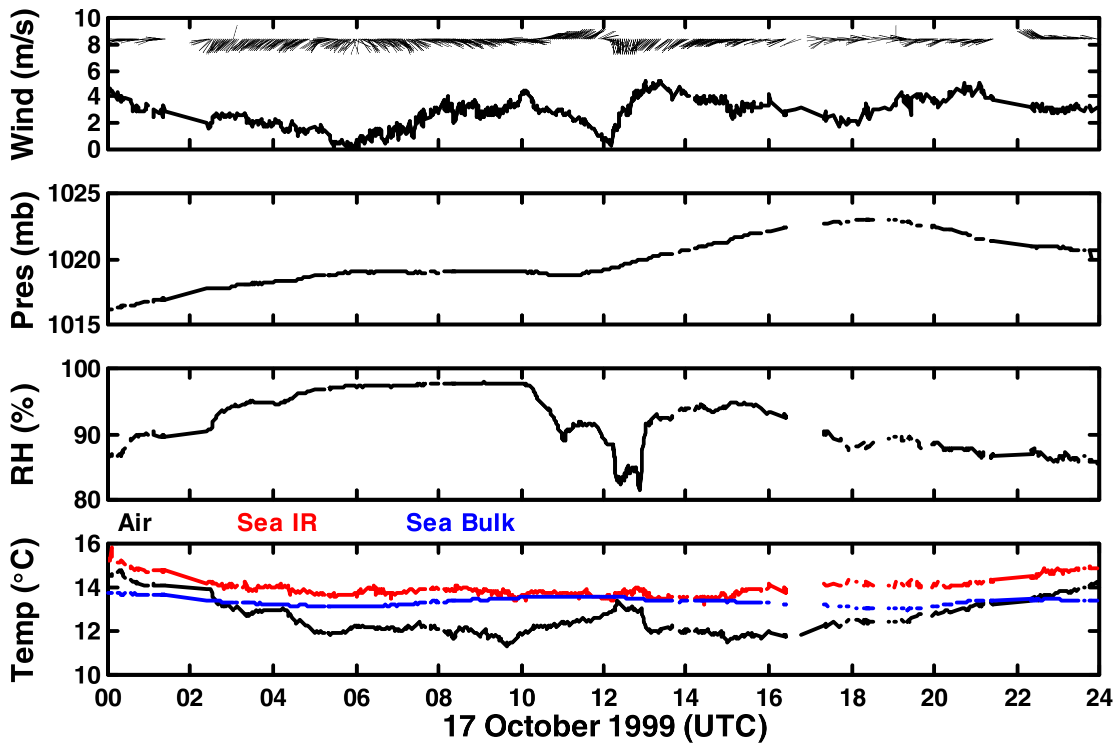


Parameter	Sensor Descrip.
Bulk (Sfc-Layer and Sfc)	
Pressure	Barometer
Vector Wind	Propeller-Vane and Compass
Air Temperature	RTD Sensor
Air Humidity	Hygrometer
SST	Hull and Float Thermistor, IR
Fluctuating (Sfc-Layer and Sfc)	
Wind	Sonic Anemometer
Temperature	Sonic Anemometer
2-D Sfc Waves–swell through 2 m wind waves	Accel.-Rate Gyro System
2-D Capillary Waves–to 3 cm	Capacitance Wires (Planned)

1. Photograph and measurement specifications for the NPS Flux Buoy.

IMPACT/APPLICATIONS

The likely impacts of this research will include improved understanding of the effects of surface waves on the measurement of surface currents by HF radar installations along with an expanded capability to include the effects of surface waves within turbulence closure schemes used by primitive equation models. The application of these results should lead to fundamentally improved models and more accurate remotely sensed surface currents.



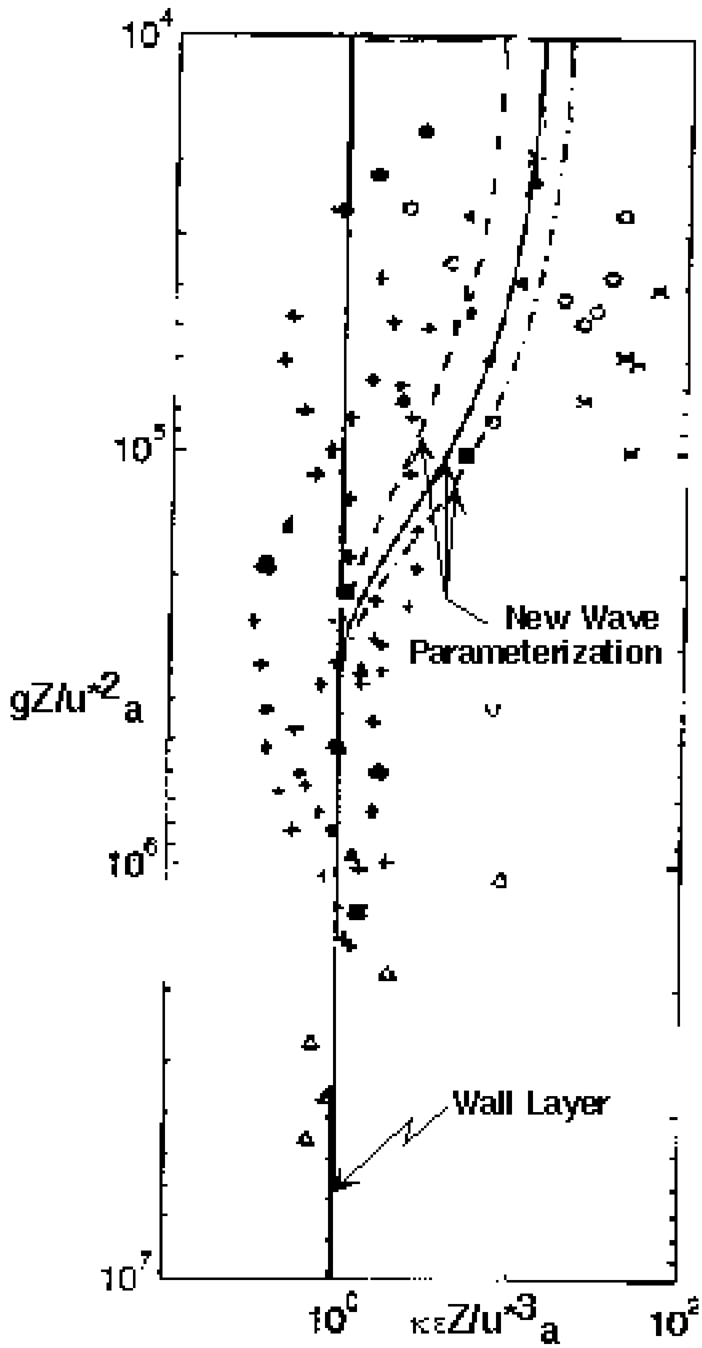
2. Real-time bulk data from the NPS Flux Buoy for 17 October 1999 (UTC) showing, from top to bottom: 1) wind speed (line) and direction from (barbs), 2) atmospheric pressure, 3) relative humidity, and 4) air temperature (black), IR-derived sea surface temperature (red), and hull-mounted thermistor sea temperature (blue).

TRANSITIONS

The transition opportunities are related to next-generation ocean circulation models and coupled atmosphere-wave-ocean models. These models will require improved parameterizations of the effects of surface waves on turbulent transport near the ocean surface. In addition, the information about the effects of surface waves on HF radar measurements will be needed to correct observed surface current fields prior to assimilation into ocean circulation models.

RELATED PROJECTS

This project represents and extension of the efforts underway as part of the Monterey Bay component of the National Ocean Partnership Program (NOPP). That project, an Innovative Coastal-Ocean Observing Network (ICON) is utilizing data from six HF radar units and four deep-ocean moorings as input to a coastal circulation model. Information about this project and the broader ICON efforts can be found at: http://www.oc.nps.navy.mil/~icon .



3. Various measurements (symbols) of nondimensional dissipation, ε, as a function of nondimensional depth adapted from Agrawal et al. (1992) along with the classic wall-layer distribution and a range of results from the new wave parameterization.

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